EVALUATION OF GROWTH RATE DIFFERENCES IN POPULATIONS OF *SARDINA PILCHARDUS* (WALBAUM, 1792) (CLUPEIDAE) FROM THE AEGEAN AND IONIAN SEAS

by

George TSERPES (1) and Nikos TSIMENIDES (2)

ABSTRACT. - *Sardina pilchardus* populations from the Aegean and Ionian seas have been examined for differences in growth rate using the statistical test described by Kappenman (1981). Results suggest that growth in both populations can be described by the same von Bertalanffy growth curve. Further studies of the spawning populations are needed to explain the one year difference observed in recruitment time between these populations, and to clarify whether they constitute different stocks.

RÉSUMÉ. - Le test statistique décrit par Kappenman (1981) a été utilisé pour étudier les différences entre les taux de croissance des populations de *Sardina pilchardus* des mers Egée et Ionienne. Les résultats mettent en évidence que la croissance de ces deux populations peut être décrite par la même courbe de von Bertalanffy. Des études ultérieures sur la reproduction seraient nécessaires pour expliquer la différence d'un an au niveau du recrutement des deux populations et pour savoir s'il s'agit de deux stocks différents.

Key-words. - Clupeidae, *Sardina pilchardus*, MED, Aegean sea, Ionian sea, Growth rate.

The sardine (*Sardina pilchardus* Walb., 1792) is one of the most exploited pelagic fish in the Greek seas. Although it inhabits the coastal and offshore waters in the entire area of the Aegean and Ionian seas, the principal fishing grounds are situated in the northern Aegean, while the main fishing grounds in the Ionian sea are located in the central part of the area. The fishes in both areas are caught by identical purse-seine techniques.

Monthly random samples of sardine were taken during the fishing seasons (March-October) of 1983 and 1984 from commercial catches unloaded at the main quays of the fishing ports of Kavala and Patra located in the northern Aegean and central Ionian seas respectively. They showed a noticeable difference in their length composition, such that catches from Kavala consisted of larger individuals than those from Patra in almost all samples taken (Figs 1, 2), although the fishing method is identical in both areas.

It is known that within a unit stock there can be large and consistent differences in size and age composition between catches from different fishing grounds. The genetic findings by Spanakis *et al.* (1989) that sardines from the Aegean and Ionian seas do not form one panmictic population, in conjunction with the above mentioned observations of their length composition, stimulated us to examine whether there are differences in growth rates between the sardine populations of the two areas.

---

(1) Institute of Marine Biology of Crete, P.O. Box 2214, 71003 Iraklion, GREECE.
(2) University of Crete, Department of Biology, Iraklion, GREECE.

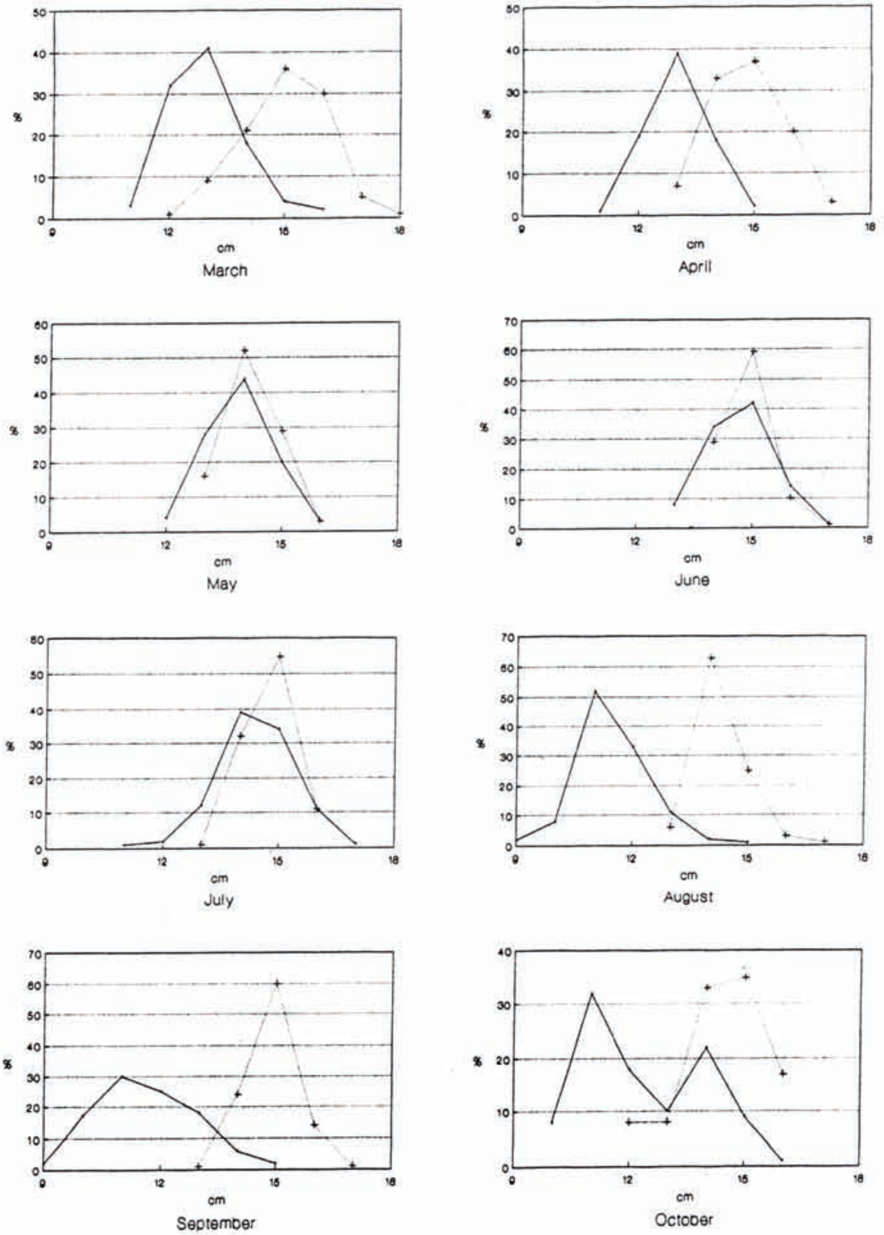

Fig. 1. - Length frequency distribution of sardine samples taken from the ports of Patra (continuous line) and Kavala (dotted line) in 1983.

Several attempts have been made in the past to provide information on sardine growth in the Mediterranean (Murat, 1935; Rodriguez-Roda and Larraneta, 1954, 1955; Sinovcic, 1984; Bouchereau and Ghazi, 1988); however, no growth studies exist for the populations in the Aegean and Ionian seas. This paper

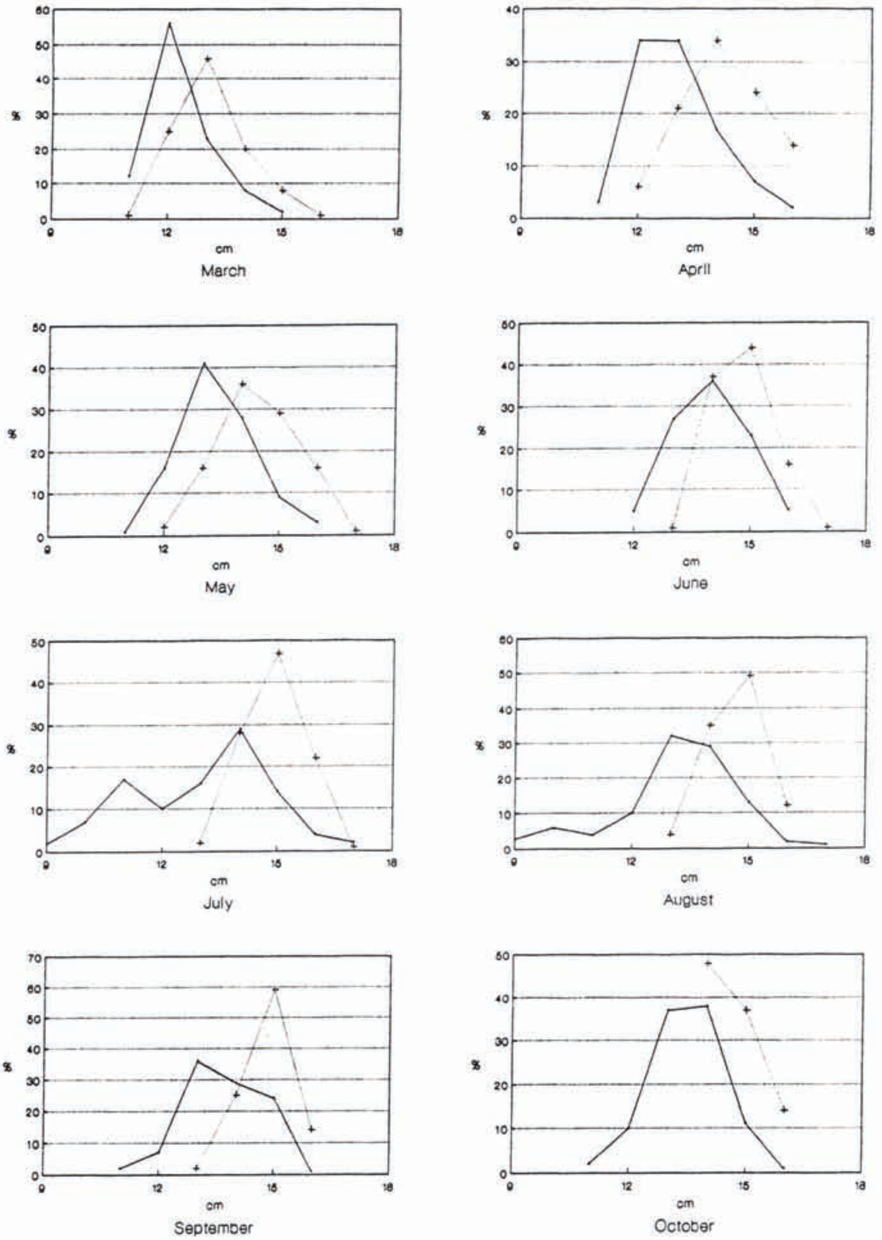

Fig. 2. - Length frequency distribution of sardine samples taken from the ports of Patra (continuous line) and Kavala (dotted line) in 1984.

is primarily concerned with the evaluation of the observed differences in length composition of sardine populations from the above areas, in terms of growth rate, but also with the actual growth of sardines in these areas.

MATERIAL AND METHODS

A thousand sardines were obtained from commercial purse-seine catches from the fishing ports of Patra and Kavala in the Ionian and Aegean seas. Samples were taken monthly (50 individuals from each port) from March 1983 to October 1984. Animals were taken randomly from the catches unloaded in the quays previously to their separation by size. For each fish the total length (TL) to the nearest mm was measured, the sex was determined by gross examination of the gonads, and several scales were removed from the region below the pectoral fin. Since sardines loose their scales very easily, if scales were not found in that region then others were taken from nearby. Six scales from each specimen were cleaned with water, placed on a 0.3 mm thick cellulose acetate plastic plate and pressed at a temperature of 95°C for two minutes. In this way the prints of the scales were left on the plate when the scales were removed. The prepared plates with the prints of the scales were read using an image processing system, consisting of a computer equipped with a frame grabber, a video-camera, a monitor and a software package (Anonymous, 1987). The image of the scales was captured by the video camera, digitized by the frame grabber and displayed on the monitor. It was possible to age the scales automatically because the software was able to judge the different luminance values of the various image areas and then mark certain bright or dark zones. However, in practice, it was necessary to interfere manually in order to eliminate false marks or to add missing ones. All prints were read in order to find the most readable one which was used for age determination. The number of annuli from this print was used to estimate the age of each specimen. Scale prints were read twice by a single reader. To reduce subjective bias in age estimations, where possible, an interval of 3 months separated the two readings. When the two readings of the same print resulted in different age estimates, the scales were considered to be unreadable.

Sex composition of the samples was compared for independence of sampling port using the chi-square test.

The von Bertalanffy growth curves for the two supposed populations were compared using the method described by Kappenman (1981), i.e. the data sets from the two areas were used in order to decide which of two models, M_1 or M_2, is preferred; in M_1 the growth curves for the two populations are the same, while in M_2 the two populations have different growth curves. According to this method, for each particular age-length observation two curves were constructed (one for each model), without taking into account this observation, and the predicted lengths in each model, as well as the squared differences between predicted and observed lengths have been computed. The latter have been summed and the model giving the smallest sum was adopted. In the present study the mean lengths at age were used instead of the raw age-length data. However this modification does not affect the reliability of the Kappenman method. Differences in mean observed lengths at age for the samples from the different ports were tested for significance using single classification analysis of variance (ANOVA). Finally, estimates of theoretical growth in length under the preferred model were obtained by fitting the observed mean length at age data to the von Bertalanffy growth equation using the Newton iteration method (Sparre, 1987). All statistical inferences were based on a significance level of $a = 0.05$.

RESULTS

The sex ratios for all sampled individuals and for the ones which had been aged are shown in table I. In both cases the chi-square test detected a slightly significant difference in sex composition of samples taken from the two ports (x^2 =

4.97 and 4.09 respectively, where $x^2_{.05} = 3.84$). Therefore, specimens of both sexes were combined for age and growth estimations.

Table I. - Sex ratios of sampled and aged fish.

AREA	FEMALES		MALES	
	Sampled	Aged	Sampled	Aged
KAVALA	297 (59.4%)	163 (54.3%)	203 (40.6%)	137 (45.7%)
PATRA	262 (52.4%)	119 (45.8%)	238 (47.6%)	141 (54.2%)

The calculated length at age obtained under models M_1 and M_2, compared with the corresponding mean observed lengths (Tables II, III) by using the Kappenman test, showed that growth of the populations from both seas can be described by the same curve since the sum of squares of the difference between observed and predicted lengths under model M_1 was found to be smaller than the one under M_2 (2021.94 and 2820.96 respectively). The growth curve for both populations is given by the following equation:

$$L_t = 181.23[1-e^{-0.30(t + 3.21)}]$$

where L_t = length at age t.

Table IV shows the mean observed lengths at age for both areas and the ones predicted by the common von Bertalanffy growth equation. Table IV also shows that the samples from Kavala pooled for the years 1983 and 1984 consisted of older individuals than those from Patra. It was found that the mean observed age of sardine samples from the Aegean sea was 2.85 years while that from the Ionian was 1.87.

The above mentioned difference in age composition occurs not only for the pooled data but also for those in each of the sampling years 1983 and 1984.

Table II. - Ages, mean observed total lengths and predicted lengths (mm), under models M1 and M2, for samples from Patra.

AGE	MEAN OBS. TL	PREDICTED TL UNDER M_2	PREDICTED TL UNDER M_1
0.33	120.50	117.08	114.54
0.42	122.00	117.36	118.91
·0.67	119.60	124.55	125.52
0.75	115.00	129.50	127.76
1.33	134.00	132.27	134.73
1.42	139.78	130.74	136.52
1.50	145.50	131.17	136.81
1.58	141.19	135.36	138.95
1.67	130.61	138.54	140.19
1.75	123.00	138.48	141.29
1.83	146.50	137.54	141.31
2.33	143.57	144.76	147.08
2.42	147.72	145.24	147.67
2.50	153.14	143.58	148.69
2.58	146.50	148.22	149.32
2.75	144.00	150.09	151.86
2.83	149.37	146.78	152.49
3.33	147.00	154.25	156.46
3.42	158.83	153.49	156.60
3.50	158.86	153.14	157.06
3.58	159.00	158.14	157.61
3.75	149.00	161.38	158.40
3.83	155.00	161.07	160.18
4.42	165.00	164.63	163.13
4.50	172.00	161.06	162.13

Table III. - Ages, mean observed total lengths and predicted lengths (mm) under models M_1 and M_2, for samples from Kavala.

AGE	MEAN OBS. TL	PREDICTED TL UNDER M_2	PREDICTED TL UNDER M_1
1.25	140.80	140.07	133.51
1.33	143.40	138.18	135.24
1.42	138.46	134.51	136.39
1.50	140.71	144.82	137.94
1.67	144.00	143.37	138.71
1.75	142.00	143.17	140.80
1.83	139.00	145.11	142.23
2.08	156.15	145.10	143.68
2.25	145.63	148.99	145.74
2.33	149.79	148.77	146.10
2.42	150.82	152.02	147.15
2.50	151.42	153.30	147.79
2.58	153.33	145.68	149.08
2.67	147.65	153.27	150.86
2.75	149.35	153.13	151.97
2.83	144.17	153.15	152.49
3.08	162.13	162.65	154.10
3.25	154.33	158.21	154.97
3.33	157.37	158.46	155.96
3.42	159.50	159.12	156.60
3.50	154.62	155.65	156.99
3.58	158.00	160.99	157.59
3.67	156.33	161.07	158.40
3.75	155.00	158.59	159.29
3.83	153.60	158.54	160.39
4.08	170.00	158.46	160.76
4.33	170.00	164.29	162.64
4.42	166.00	160.35	162.58
4.50	162.00	164.43	162.86
4.58	165.00	162.50	164.34
4.75	164.25	168.49	165.09
4.83	161.00	183.91	166.40

Table IV. - Age group frequencies and mean total lengths observed and predicted by the von Bertalanffy length at age for aged fish.

AREA	AGE	FREQUENCY			OBS. TL	BERT. TL
		1983	1984	Total		
Patra	0	36	4	40 (15.4%)	119.27	112.05
	1	40	72	112 (43.1%)	137.23	129.98
	2	38	44	82 (31.5%)	147.38	143.26
	3	16	7	23 (8.8%)	154.61	153.10
	4	3	0	3 (1.2%)	168.50	160.39
	0	0	0	0	-	112.05
Kavala	1	32	11	43 (14.3%)	141.20	129.98
	2	60	74	134 (44.7%)	149.81	143.26
	3	49	49	98 (32.7%)	156.76	153.10
	4	6	19	25 (8.3%)	165.46	160.39

Specifically, it was found that the mean observed ages of samples obtained in 1983 from the ports of Kavala and Patra were 2.70 and 1.82 years respectively, while the corresponding ages of samples obtained in 1984 were 3.00 and 1.93 years.

Considering mean observed length at age between samples from the two areas ANOVA detected no significant difference after age 1 (Table V).

AGE	F-RATIO	CRITICAL F-VALUE
1	20.68	3.91
2	0.67	3.89
3	0.68	3.92
4	0.06	4.22

Table V. - Results of ANOVA tests performed to detect differences in mean observed lengths at age between samples from the different ports.

DISCUSSION

Several authors have pointed out that estimation of the von Bertalanffy growth parameters is highly affected by the composition of the sample (Paloheimo and Dickie, 1965; Southward and Chapman, 1965; Pauly, 1979). Therefore, comparison of curves obtained from samples with different length compositions makes necessary the application of a proper statistical method. The Kappenman test used in the present study is simple in its concept and seems to give reasonable results. It has shown that growth in both populations studied is represented by the same von Bertalanffy growth curve. The back calculation method was not applied in the present study since scales were not taken from the same body area in all specimens, thus they differ in size and shape.

The use of an image analysis system for scale reading was found to be more convenient, faster and gave more accurate measurements of scale and annulus radius in comparison with the traditional way of reading under a microscope. Moreover, the ability of the present system to store the results made the subsequent work of data processing easier.

Considering the differences found in length and age composition of catches from the two areas, table IV shows that they may be due to the fact that recruitment of sardines in the central Ionian sea starts one year earlier than in the northern Aegean sea. However, since the fishing season is the same in both areas and fishing is carried out by using the same gear, the exploitation pattern should not affect the time of recruitment.

Certainly a difference in time of recruitment is not unusual for populations distributed over a wide geographical range, but the difference of almost one year observed in the present study may need some additional explanation.

Spanakis *et al.* (1989) state that though their findings suggest that sardine populations from the Aegean and Ionian seas do not form a panmictic population, this is not to say that these populations constitute discrete stocks. Thus their findings and the results of the present study are in agreement with Gulland's (1983) view that average age or size is a poor parameter to use for stock differentiation.

Obviously further studies on the spawning populations are needed to clarify whether these populations do or do not constitute different stocks.

Table VI. - Length (mm) at age from different studies in the Mediterranean.

AGE	Fage (1920) (Golfe du Lion, France)	Murat (1935) (Casti--glione, Algeria)	Rodriguez and Larraneta (1954) (Castellon, Spain)	Sinovcic (1984) (Central Adriatic)	Boucherau and Chazi (1988) (Algeria)	Present study
1	98	110	141	102.18	102.93	129.98
2	129	145	166	140.09	123.89	143.26
3	141	155	189	164.02	140.63	153.10
4	149	160	194	179.13	153.99	160.39

Concerning growth rate itself, table VI summarizes results from different growth studies on sardine in the Mediterranean. Estimated values of length at age from the present study lie between the corresponding values reported for other Mediterranean areas. However, the scarcity of small individuals in the present study may have affected the estimation of the von Bertalanffy growth parameters and resulted in overestimating length, mainly at age 1, but this does not affect the method applied for growth curve comparisons (Kappenman, 1981).

REFERENCES

ANONYMOUS, 1987. - Optical Pattern Recognition System. (Ver. 1.08) Biosonics, Inc. Seattle, WA 98105.

BOUCHEREAU J.L. & M. GHAZI, 1988. - Paramètres de croissance de *Sardina pilchardus* (Walbaum, 1972), de la baie de Beni-Saf (Algèrie). *Rapp. Comm. int. Mer. Médit.*, 31(2): 267.

FAGE L., 1920. - Engraulidae, Clupeidae. *Rep. Dan. Ocean. Exp. 1908-10 Med. adj. Seas.* A. 9 II: 34-140

GULLAND J.A., 1983. - Fish stock assessment, a manual of basic methods. FAO/Series on Agriculture 1. J. Wiley & Sons, London.

KAPPENMAN R.F., 1981. - A method for growth curve comparisons. *Fish. Bull.*, 79(1): 95-101.

MURAT M., 1935. - Contribution à l'étude de la sardine (*S. pilchardus* [Walb.]) de la baie de Castiglione. *Bull. Stat. Aquic. Peche Castiglione*, 1933, 2: 93-196.

PALOHEIMO J.E. & M.L. DICKIE, 1965. - Food and growth of fishes. A growth curve derived from experimental data. *Fish. Res. Bd. Canada.*, 22(2): 521-542.

PAULY D., 1979. - Gill size and temperature as governing factors in fish growth: a generalization of Von Bertalanffy's growth formula. *Ber. Inst. Meereskd*, 63: 156 pp.

RODRIGUEZ-RODA J. & G.M. LARRANETA, 1954. - Consideraciones sobre el control de la pesqueria de sardina (*Sardina pilchardus* [Walb.]) de la costa de Castellon. *Proc. Inst. Biol. Apl.*, 16: 5-30.

RODRIGUEZ-RODA J. & G.M. LARRANETA, 1955. - The growth rate of the Sardine (*Sardina pilchardus* [Walb.]) off the coast of Alicante in relation to that of Castellon. *Conseil général des pêches pour la Méditerranée, Débats et documents techniques*, No 3, FAO Rome: 61-66.

SINOVCIC G., 1984. - Summary of biological parameters of sardine (*Sardina pilchardus* Walb.) from the central Adriatic. *FAO Fish. rep.*, (290): 147-148.

SOUTHWARD G.M. & D.G. CHAPMAN, 1965. - Utilization of Pacific halibut stocks: study of Bertalanffy's growth equation. *Int. Pac. Halibut. Comm.*, 39: 1-33.

SPANAKIS E., TSIMENIDES N. & E. ZOUROS, 1989. - Genetic differences between populations of sardine, *Sardina pilchardus*, and anchovy, *Engraulis encrasicolus*, in the Aegean and Ionian Seas. *J. Fish Biol.*, 35: 417-437.

SPARRE P., 1987. - Computer programs for fish stock assessment. Length-based fish stock assessment (LFSA). *FAO Fish. Tech. Rap.*, 101(Suppl. 2): 218 pp.

Reçu le 26.03.1990.
Accepté pour publication le 19.12.1990.